

# Early Feeding and Energetics of Lake-Rearing Chinook Salmon

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*With support from METRO King County and the WDFW*

# Is food supply a major limiting factor for lake-rearing juvenile chinook?

- Little known about how juvenile chinook utilize lake habitats
- Is Lake-rearing a viable alternative to “stream-type” & “ocean-type” strategies
- What do they eat? When? How much?
- Evaluate feeding/rearing conditions in the lake from growth performance and consumption

**In  
estuaries-**



**Well-studied: aquatic insects (midges),  
terrestrial insects, epibenthic  
crustaceans, zooplankton**

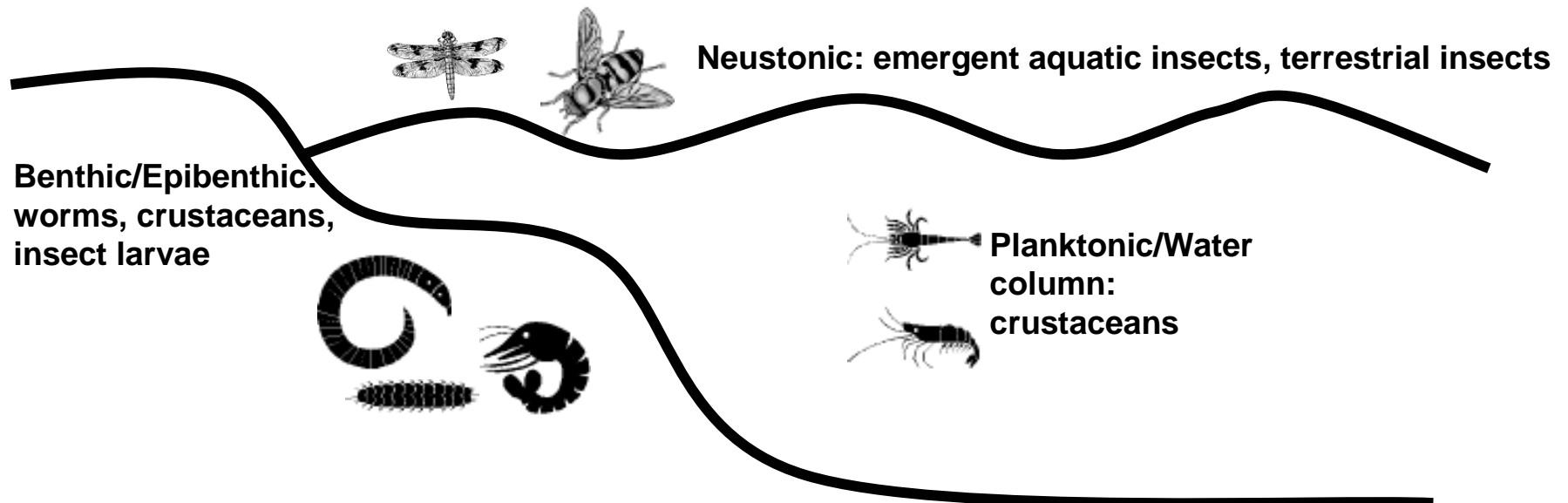
(Dunford 1975; Levings *et al.* 1991; Kjelson *et al.* 1982; Healey 1998; Cordell *et al.* 2001)

**In lakes?**



**Only one study! *Stream-type chinook* in  
the littoral zone of a *pristine lake* ate:  
aquatic insects, terrestrial insects, and  
zooplankton**

(Clemens 1934)

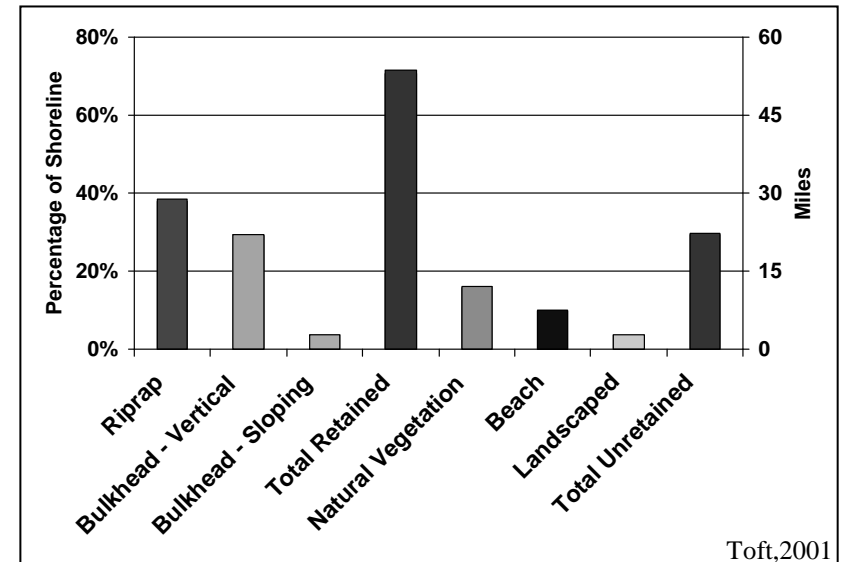




**Lake Washington,  
circa 1890...**



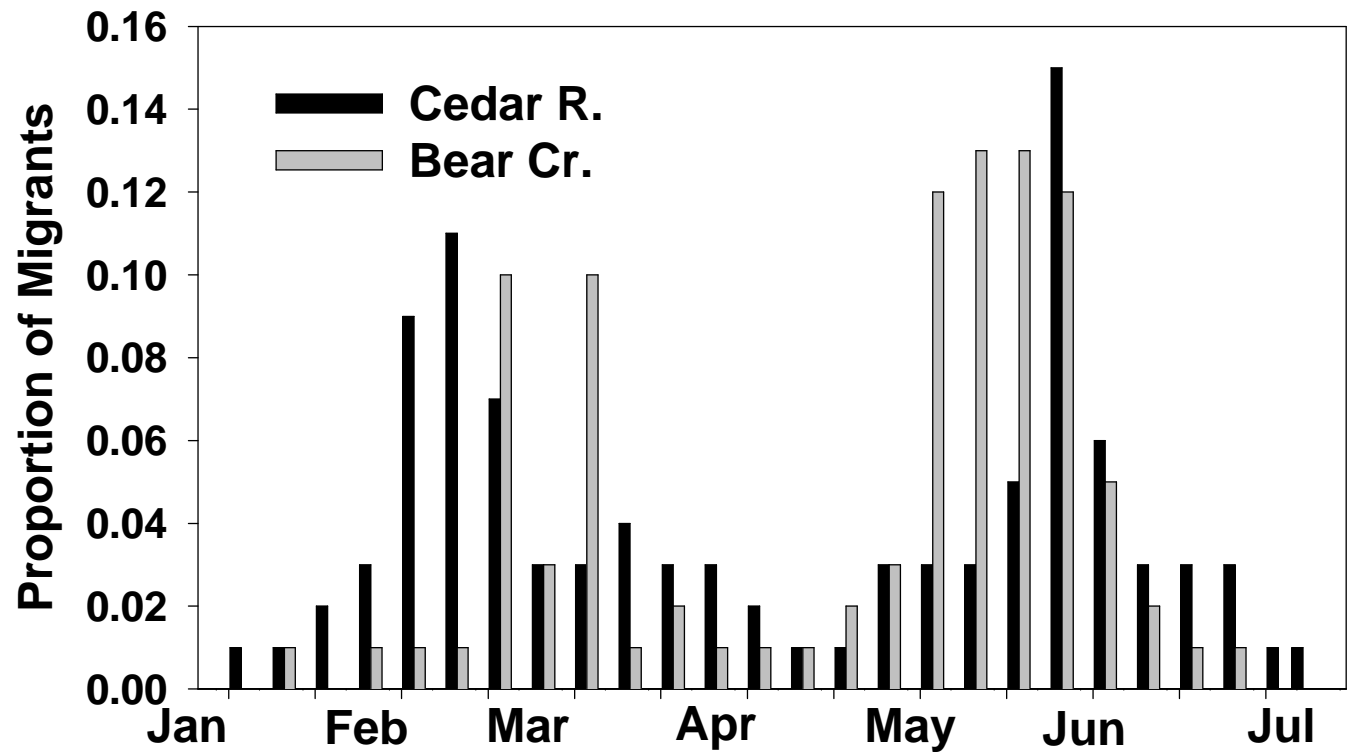
**Lake Washington, 2003**



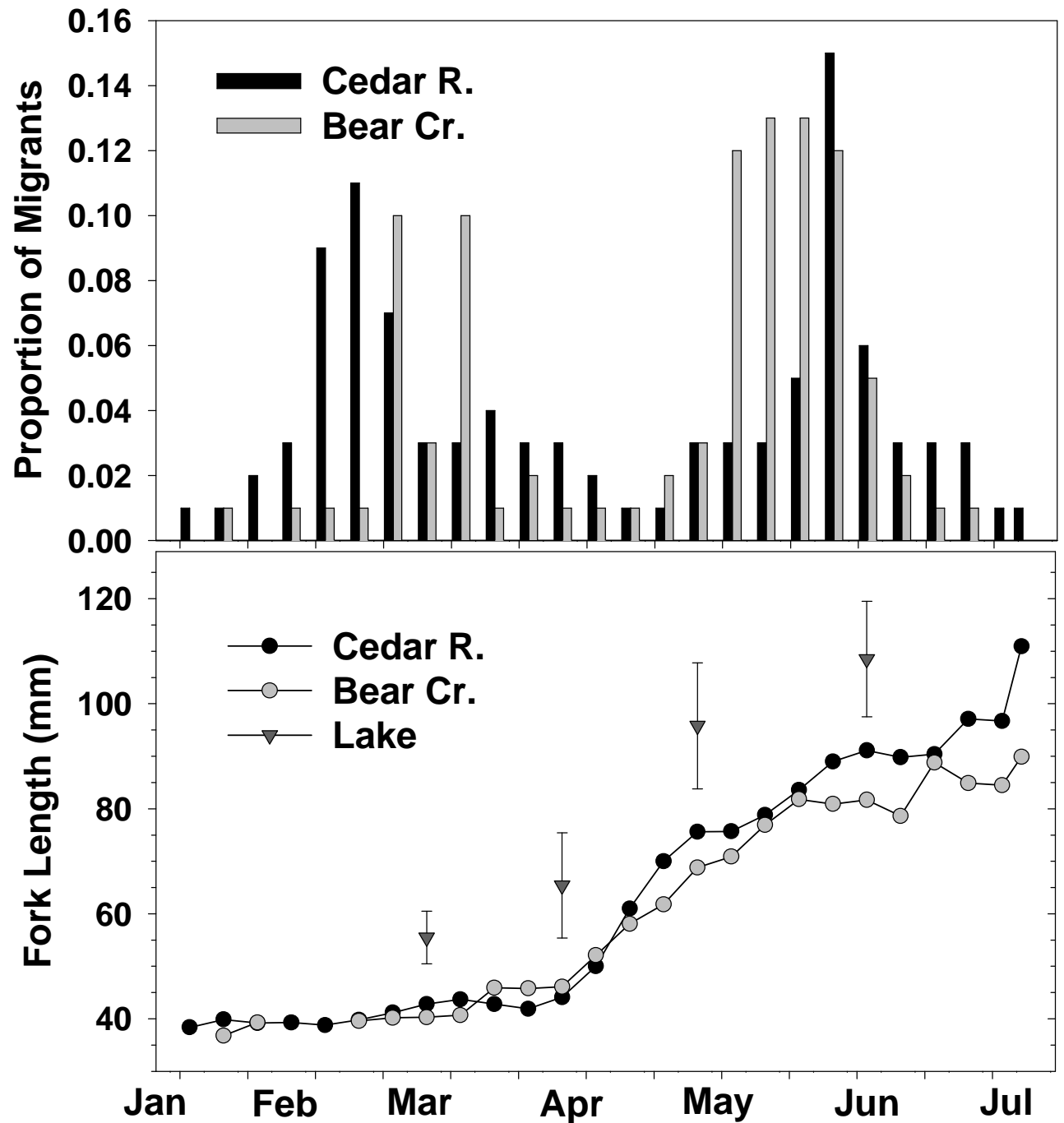


# Wild Chinook Lake-Entry Timing Patterns

Wild chinook migration  
Is bimodal from both  
Cedar R & Bear Cr



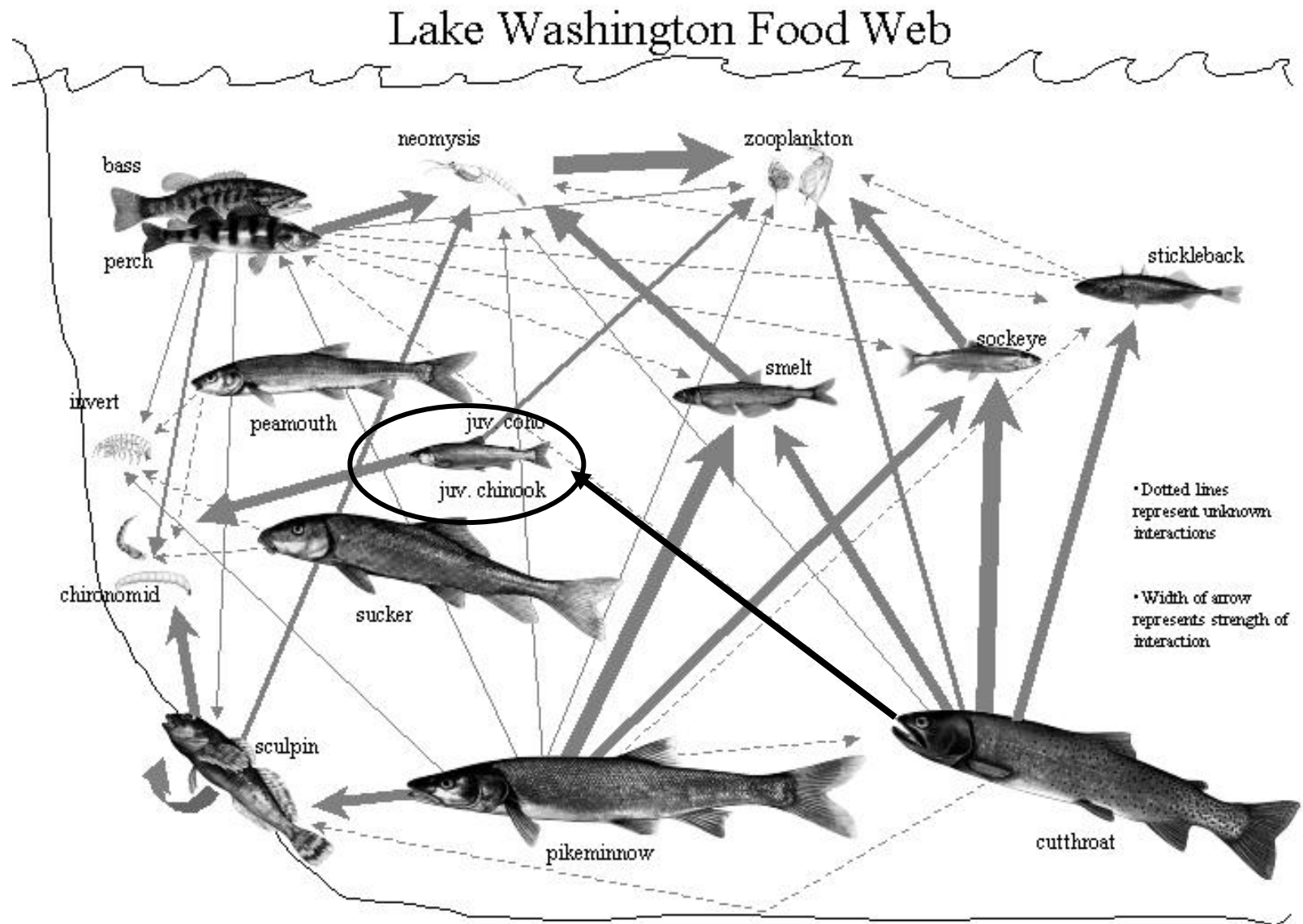
Wild chinook migration  
Is bimodal in both  
Cedar R & Bear Cr



Fry migrants remain  
small at Lake-entry  
through early April

Fry in the lake are  
Larger than new entries

# Quantifying Trophic Linkages. Interaction Strength may vary among seasons or between life stages



# Use Bioenergetics Model to Estimate the Amount of Food needed to Satisfy Growth

- **$C = M + W + G$**

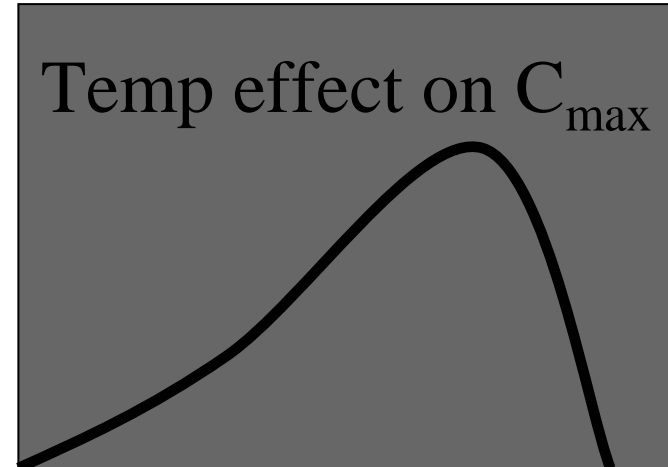
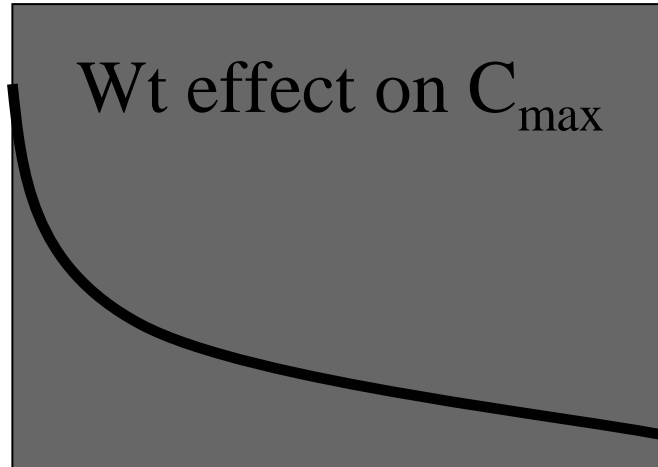
- **Cons.** =  $f(\text{Body Wt, Temp, Prey energy})$
- **Metabolism** =  $f(\text{Body Wt, Temp, Activity})$
- **Waste** =  $f(\text{Ration size, Temp for some spp})$
- **Growth (g)** =  $\text{Net energy (J)} / \text{Energy density (J/g)}$ 
  - Growth can be (+ or -) somatic or gonadal tissue

# Characteristic Curves

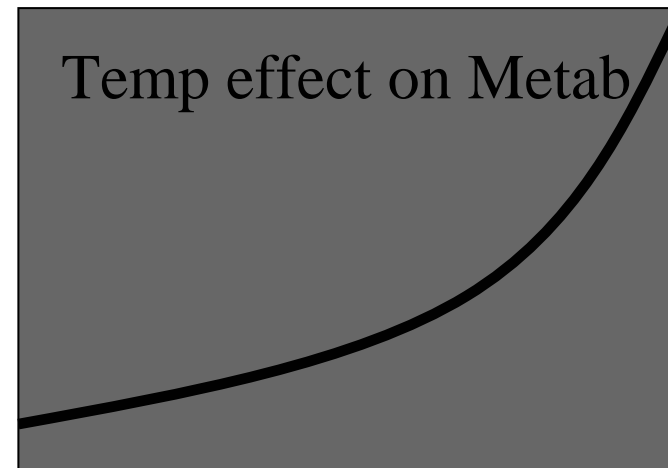
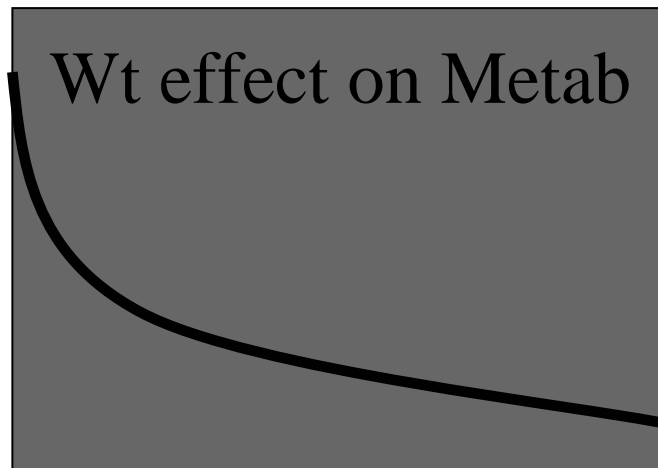
Weight Effects

Temperature Effects

$C_{\max}(\text{g}/(\text{g}/\text{d}))$



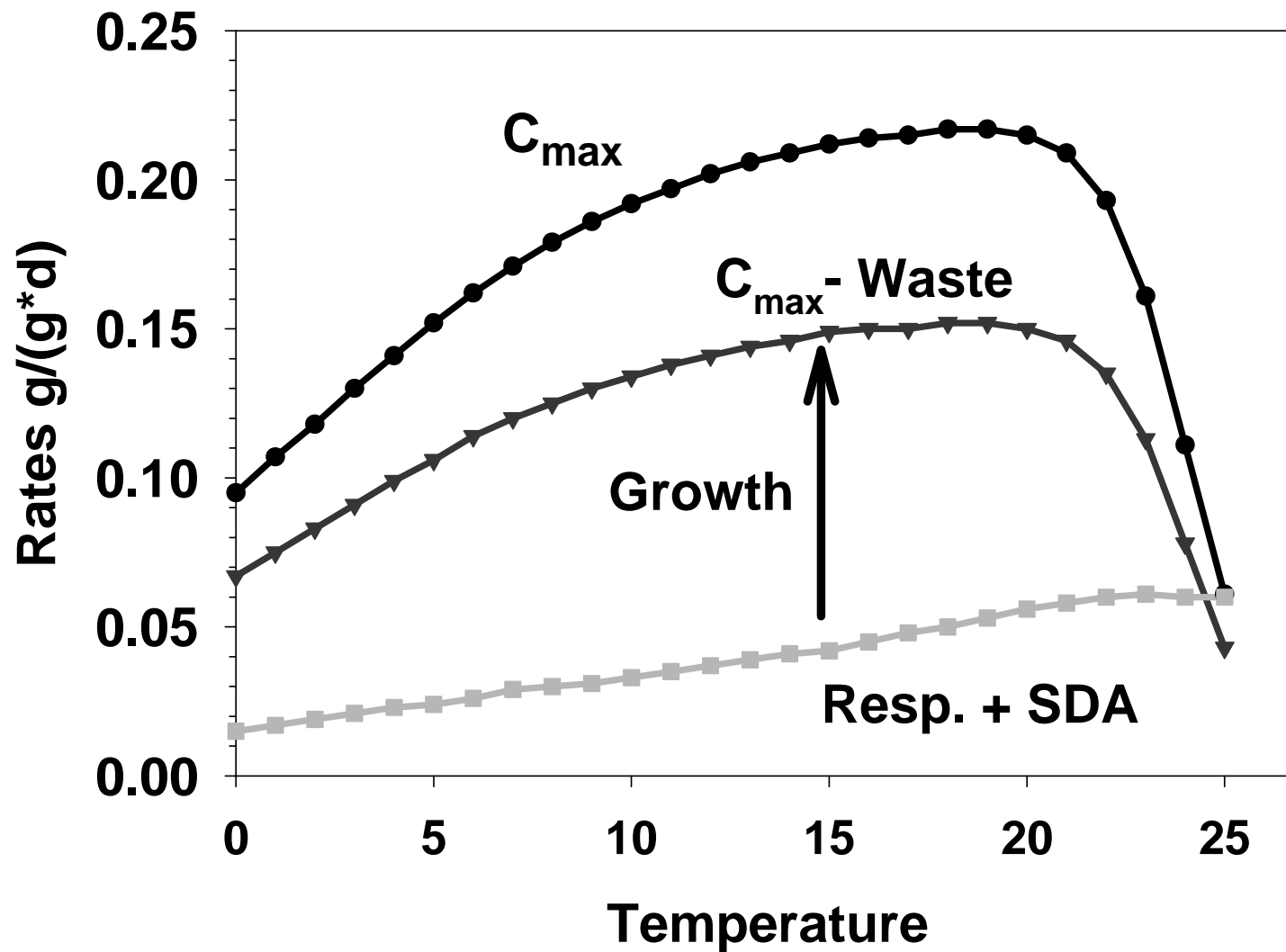
$\text{gO}_2/(\text{g}/\text{d})$



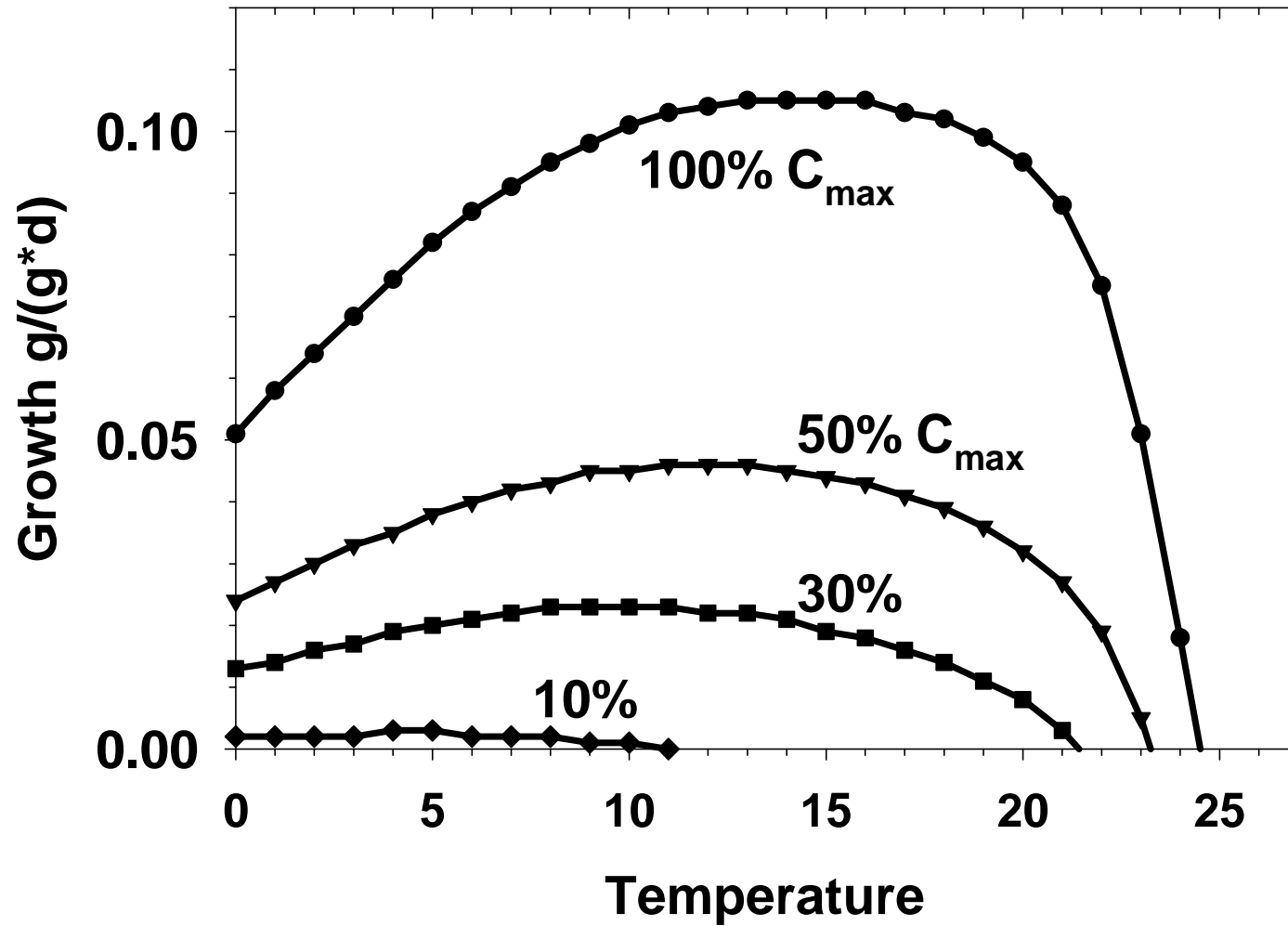
Weight (g)

Temperature ( $^{\circ}\text{C}$ )

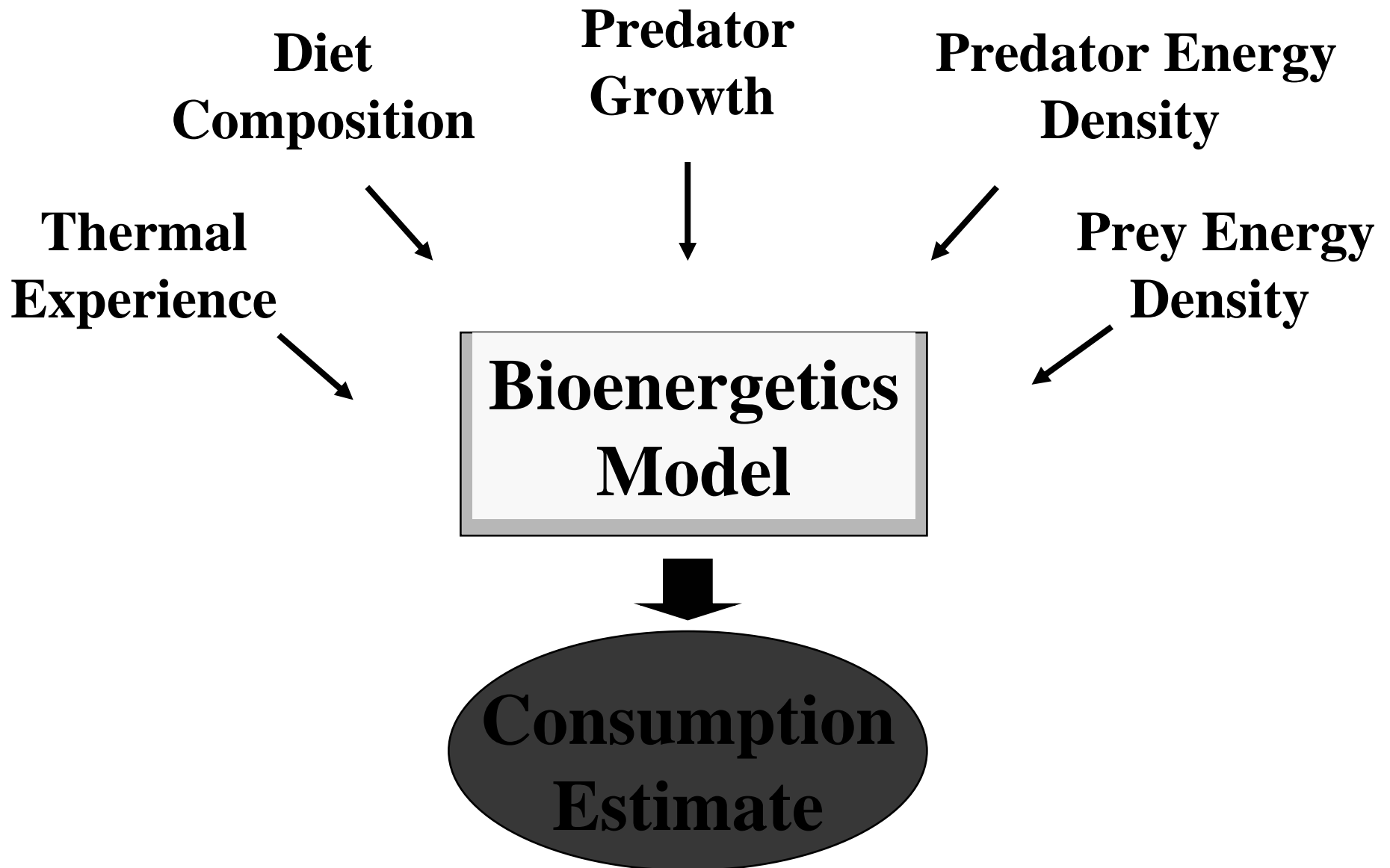
# Temperature-Dependent Energy Budget



# Optimal Temperature Declines with Declining Ration

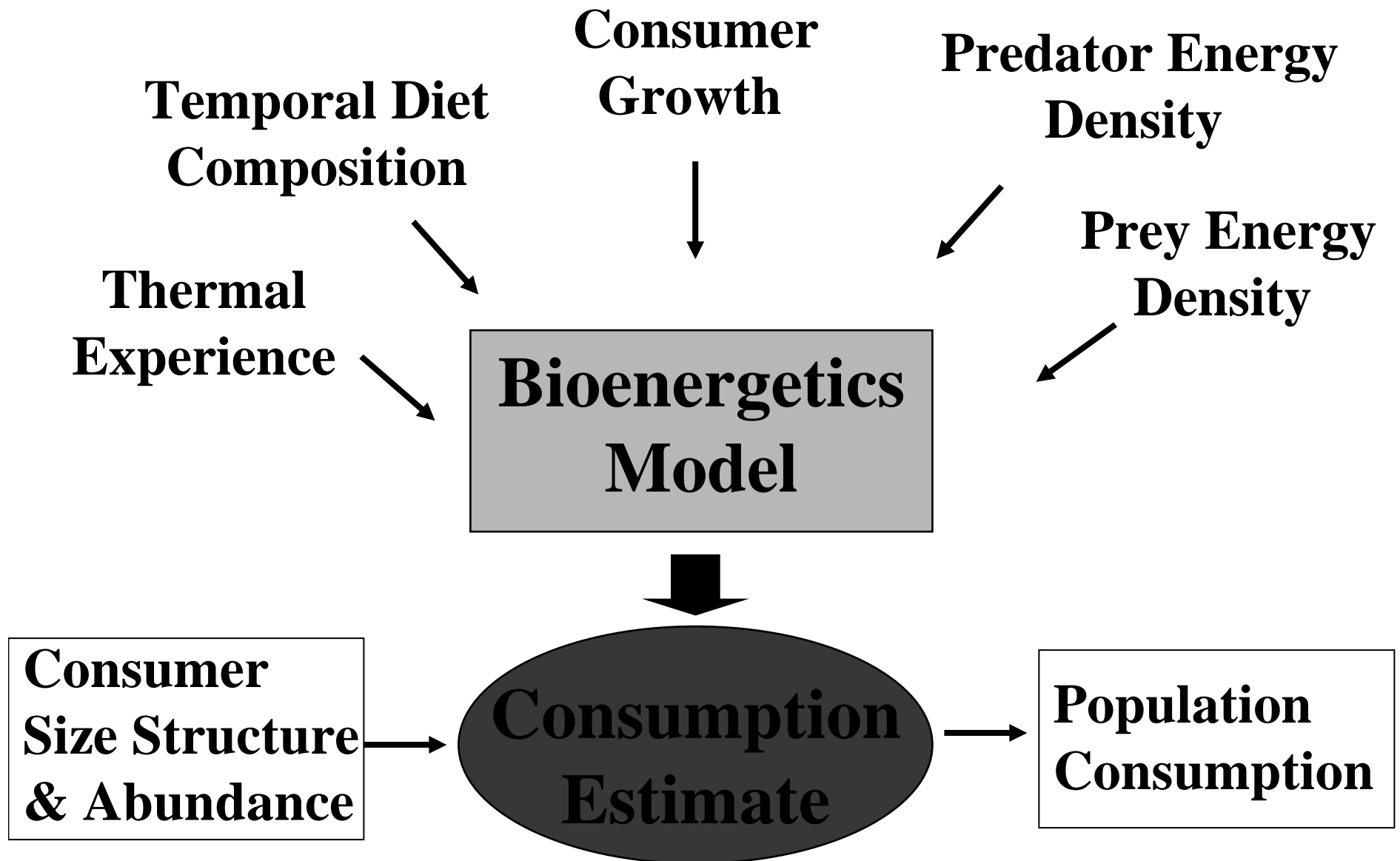


# Modeling Process

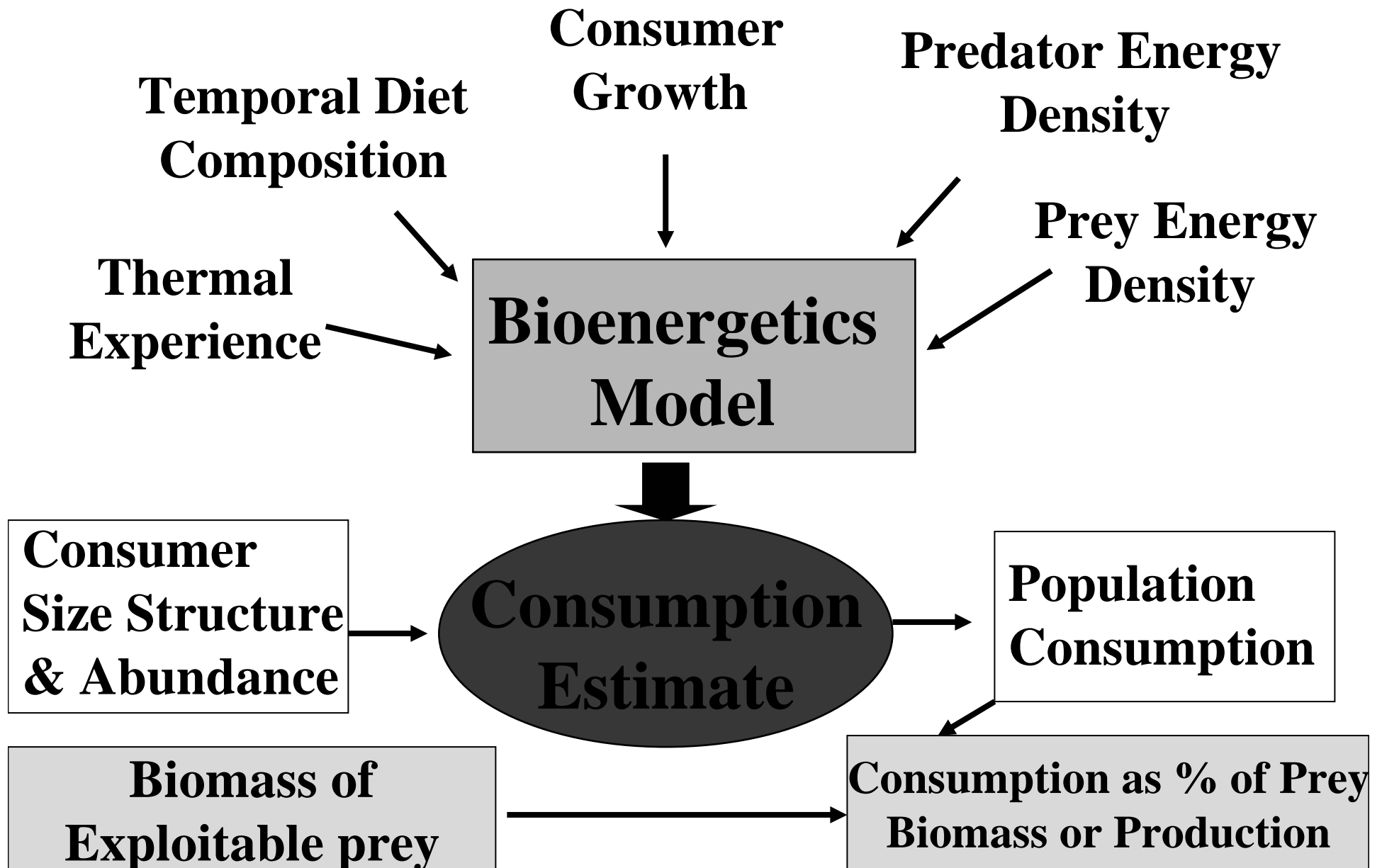




# Modeling Process

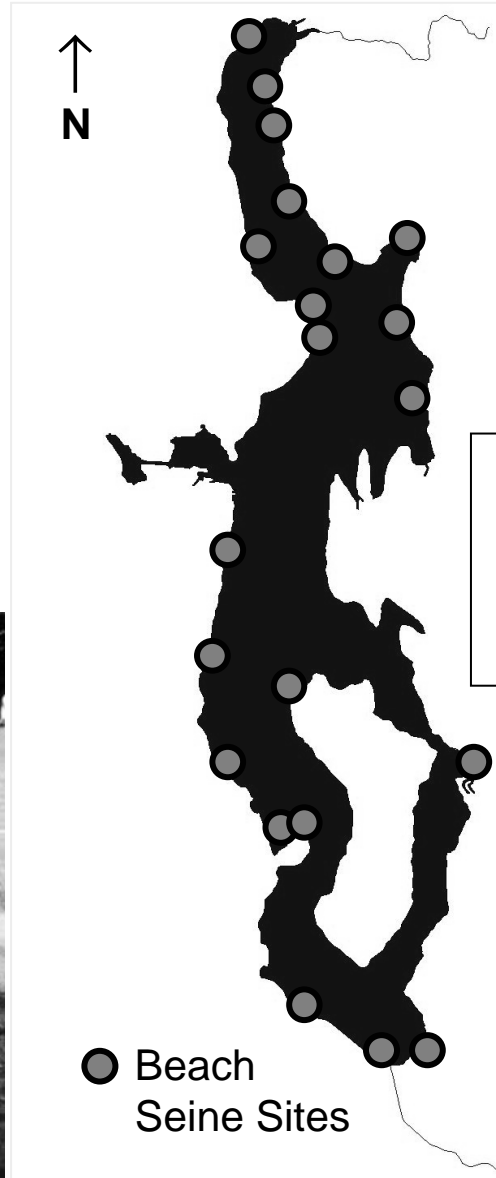


# Modeling Process



# SAMPLING DESIGN

- 1999 and 2000
- March through June
- WDFW beach seine crew
- 30 m seine, 10 m from shore
- Sites throughout the lake
- Primarily daytime



# METHODS



- Recorded fork length
- Recorded weight
- Non-lethal gastric lavage
- 250  $\mu$ m sieve
- Samples preserved in alcohol

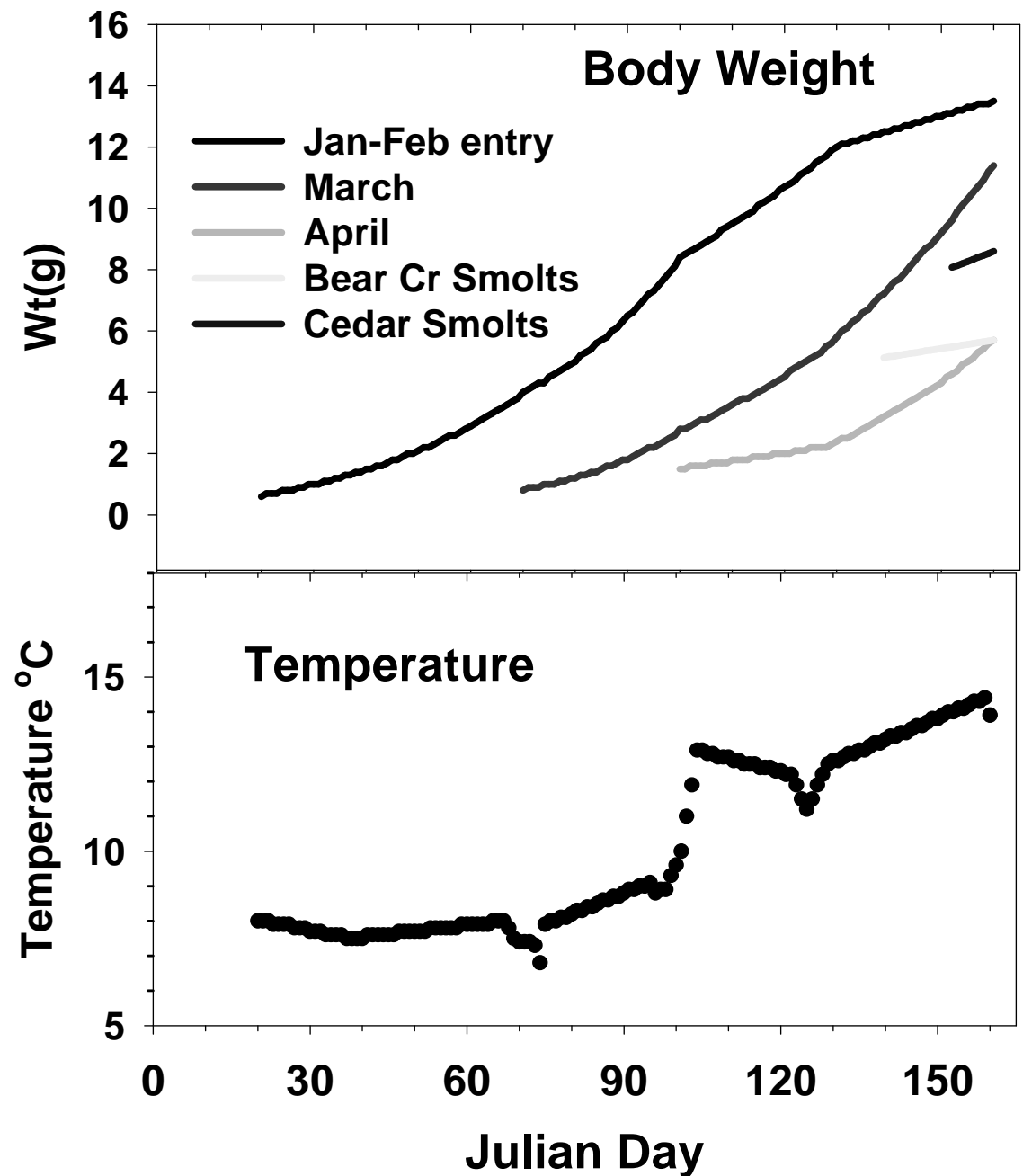
# Model Inputs

- Each entering cohort is assigned an Initial & Final Wt

- Model then grows fish according to temperature  
Diet and food quality to fit final wt

- Temperature increased Monthly

- Max. Temp. modified by fish moving into thermocline





### Daylight:

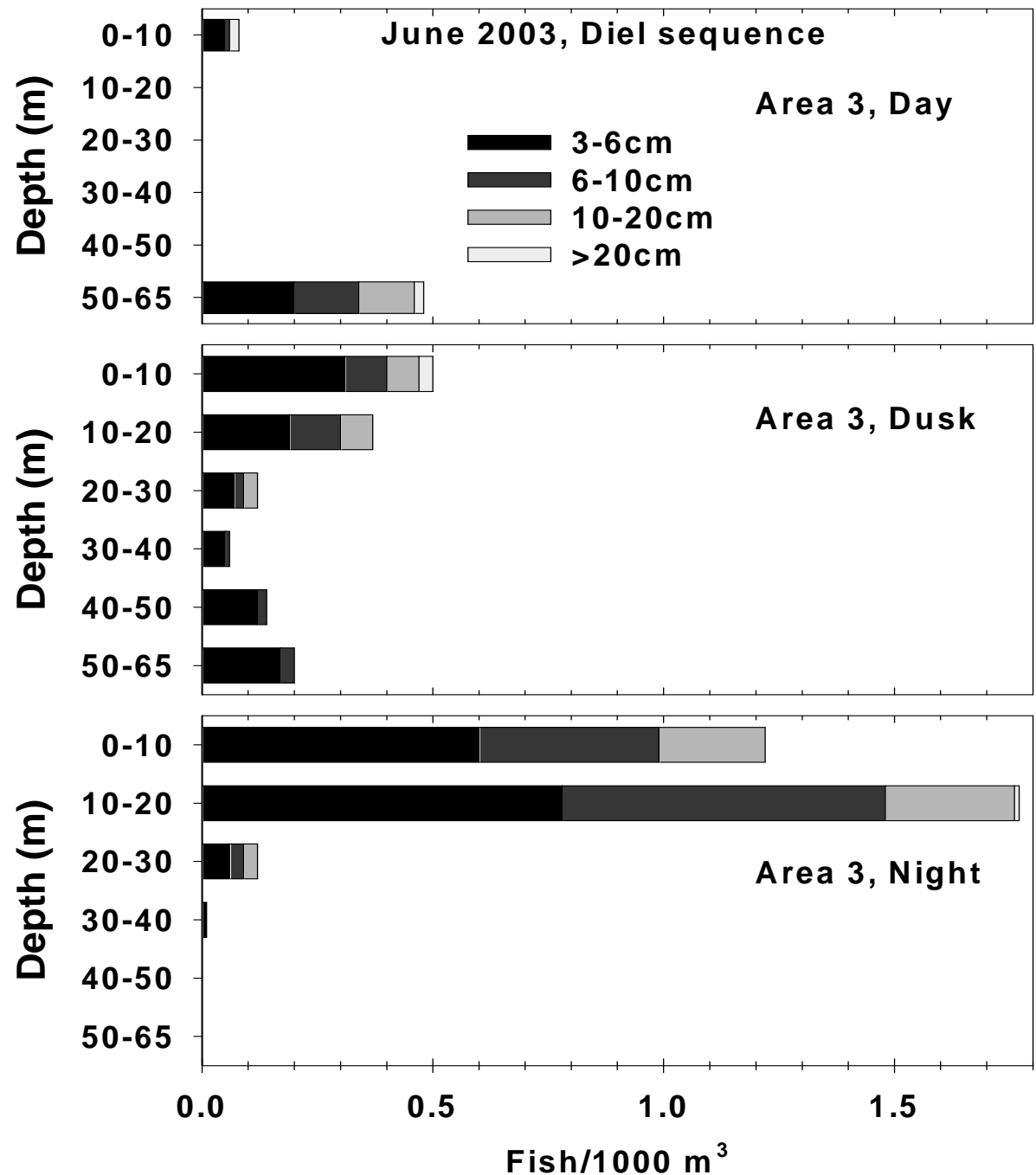
- Few fish are in the upper water column during daylight except large and very small fish
- Could be in schools, near bottom or near shore

### Dusk

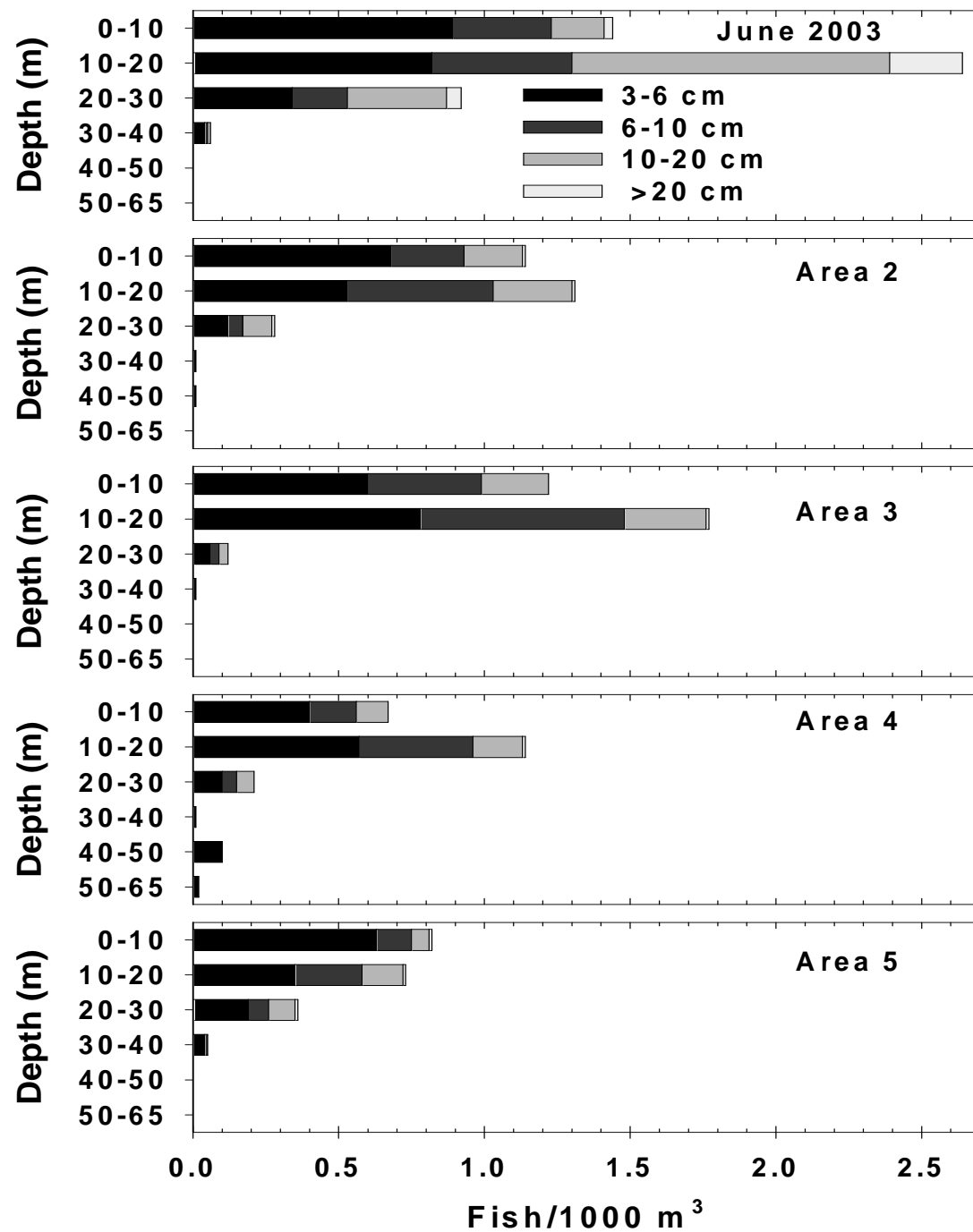
- Smolt-sized targets migrate To upper 20 m at dusk

### Night

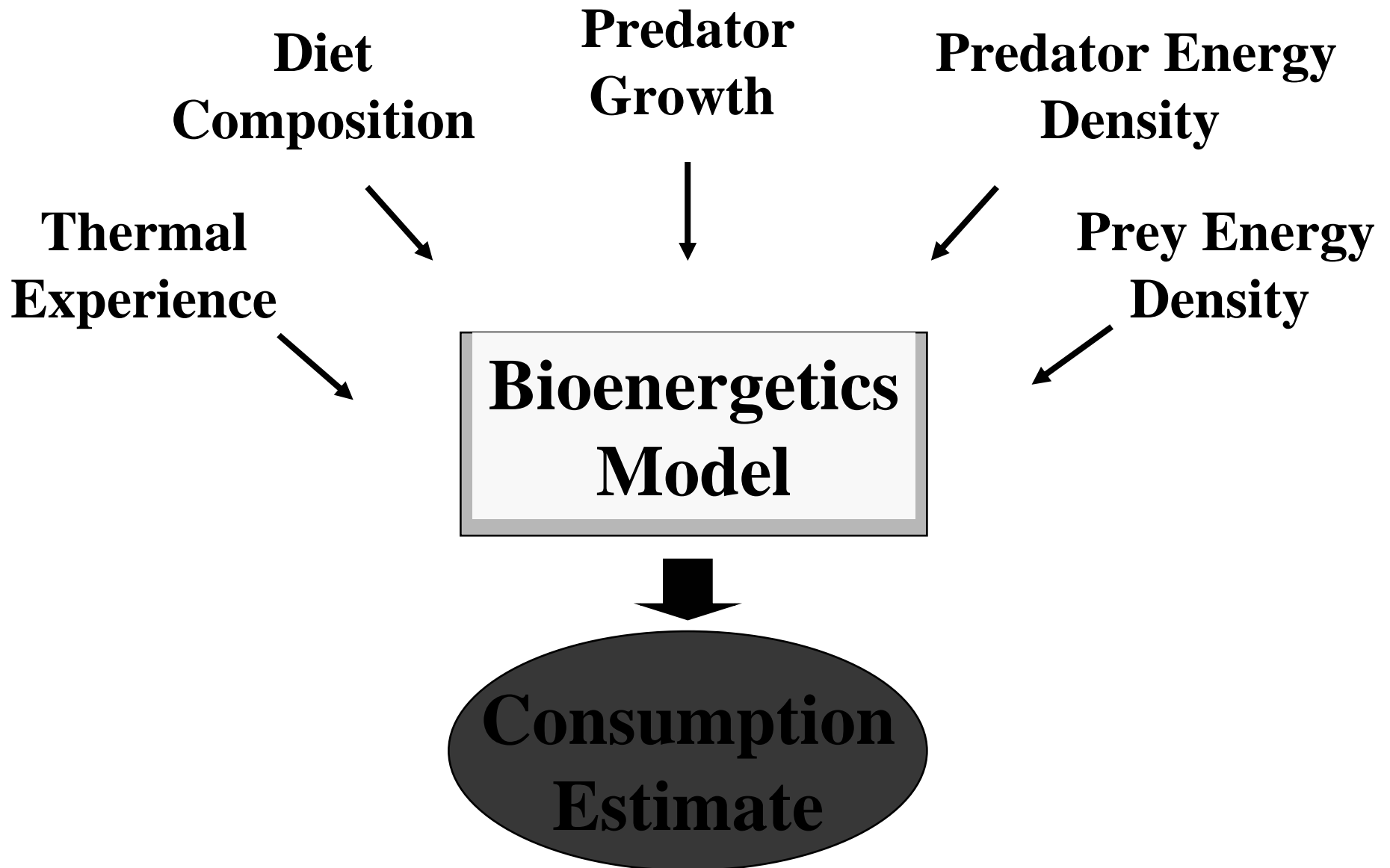
- Smolt-sized targets fully dispersed in upper 20 m at night
- Net samples confirmed that chinook, sockeye, smelt, sticklebacks & cutthroat composed most of the targets



Night:  
Highest densities were consistently  
Found in the upper 20 m  
in all areas



# Modeling Process





# RESULTS

Chinook in Lake Washington consumed emergent insect  
and zooplankton prey

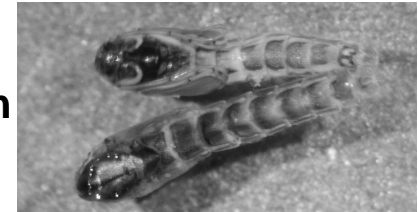
## *Daphnia* spp.:

- Larger than other zooplankton
- Seasonal presence in lake
- Consumed in water column



## Chironomids (midges):

- Larvae inhabit epibenthos
- Present through spring
- Consumed as pupae in water column & surface



## Terrestrial Invertebrates:

?



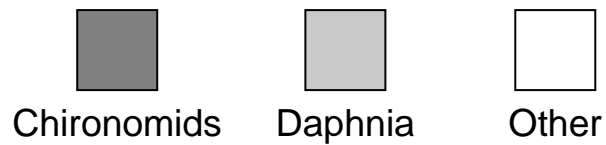
?

- Fall or blown from riparian vegetation
- Present throughout the spring
- Consumed at water's surface

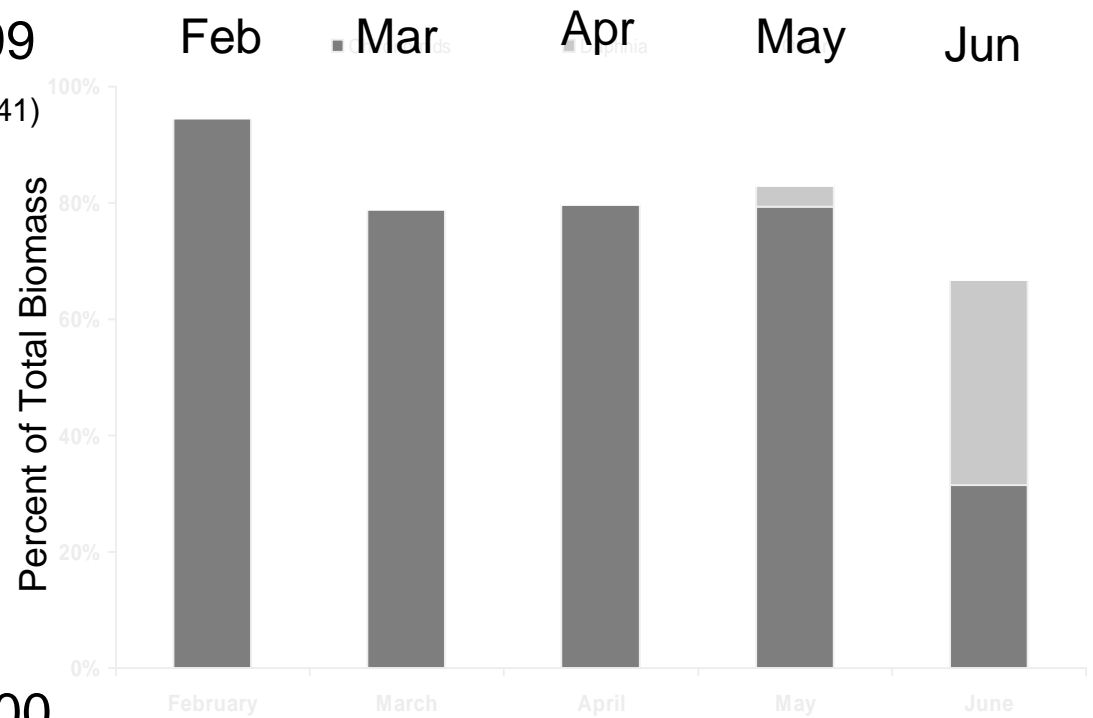
# RESULTS

## Chinook prey by month

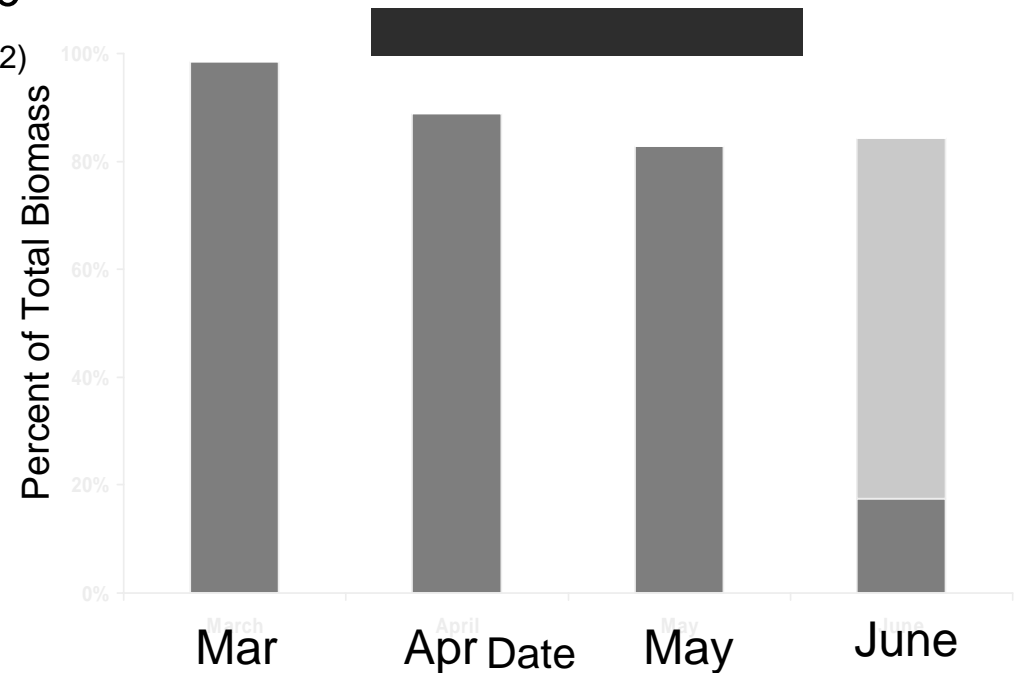
- Chinook diet changed with prey availability and fish behavior



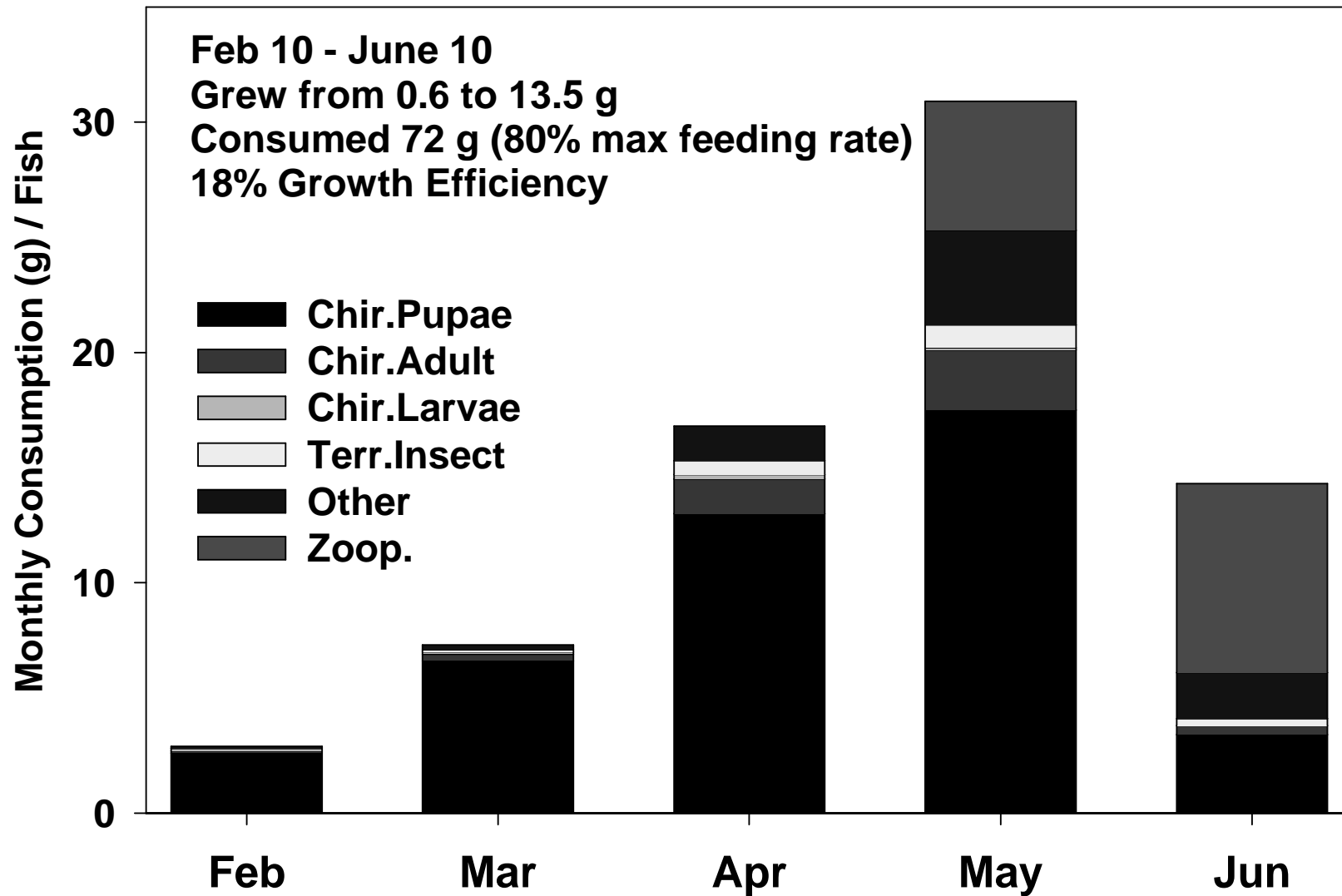
1999  
(n = 241)



2000  
(n = 222)



# Temporal Consumption Patterns of Migrant Fry



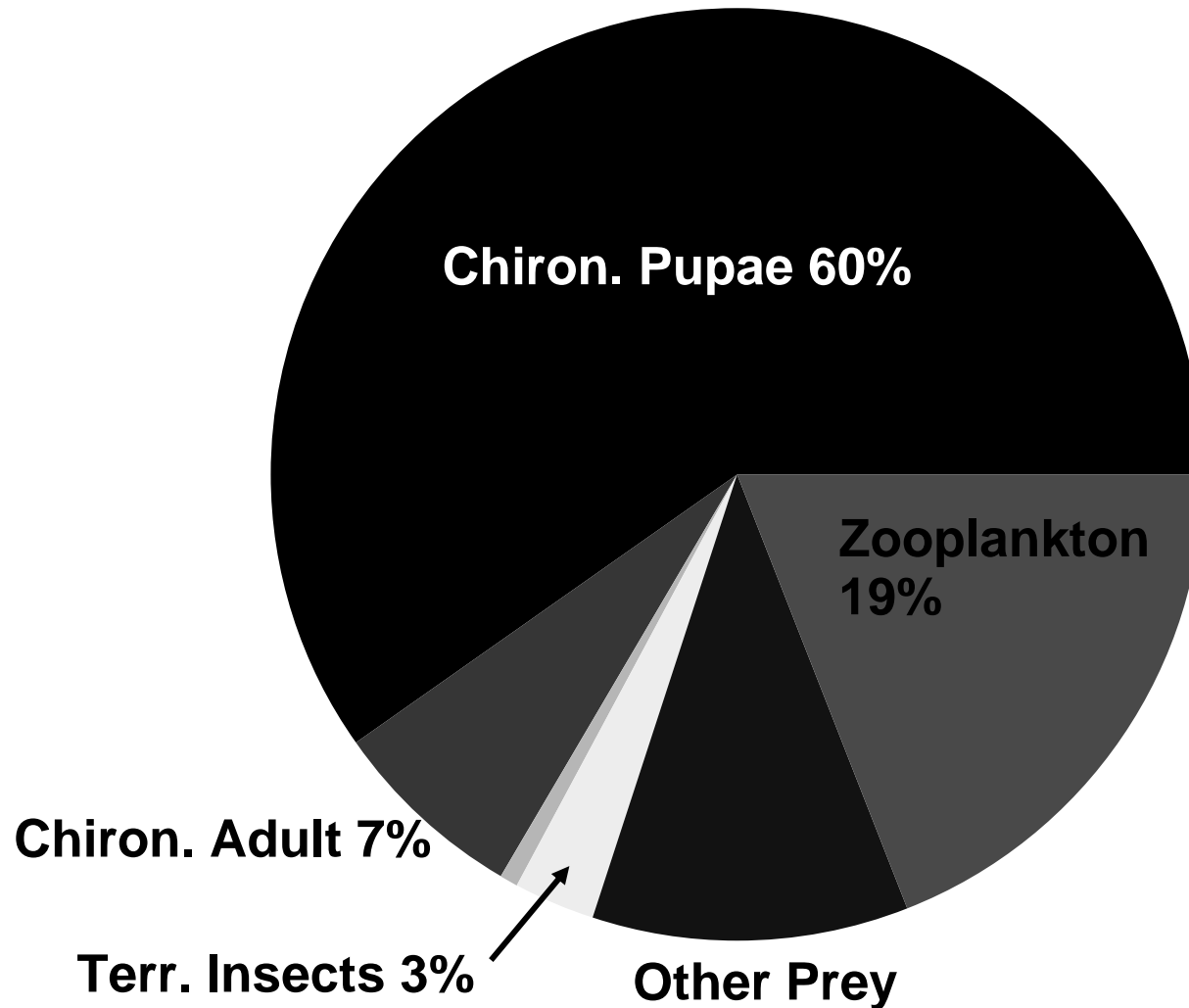
# Total Biomass Contribution over the Lake-Rearing Period

Feb 10 - June 10

Grew from 0.6 to 13.5 g

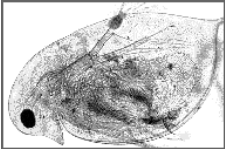
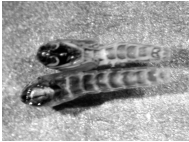

Consumed 72 g (80% max feeding rate)

18% Growth Efficiency



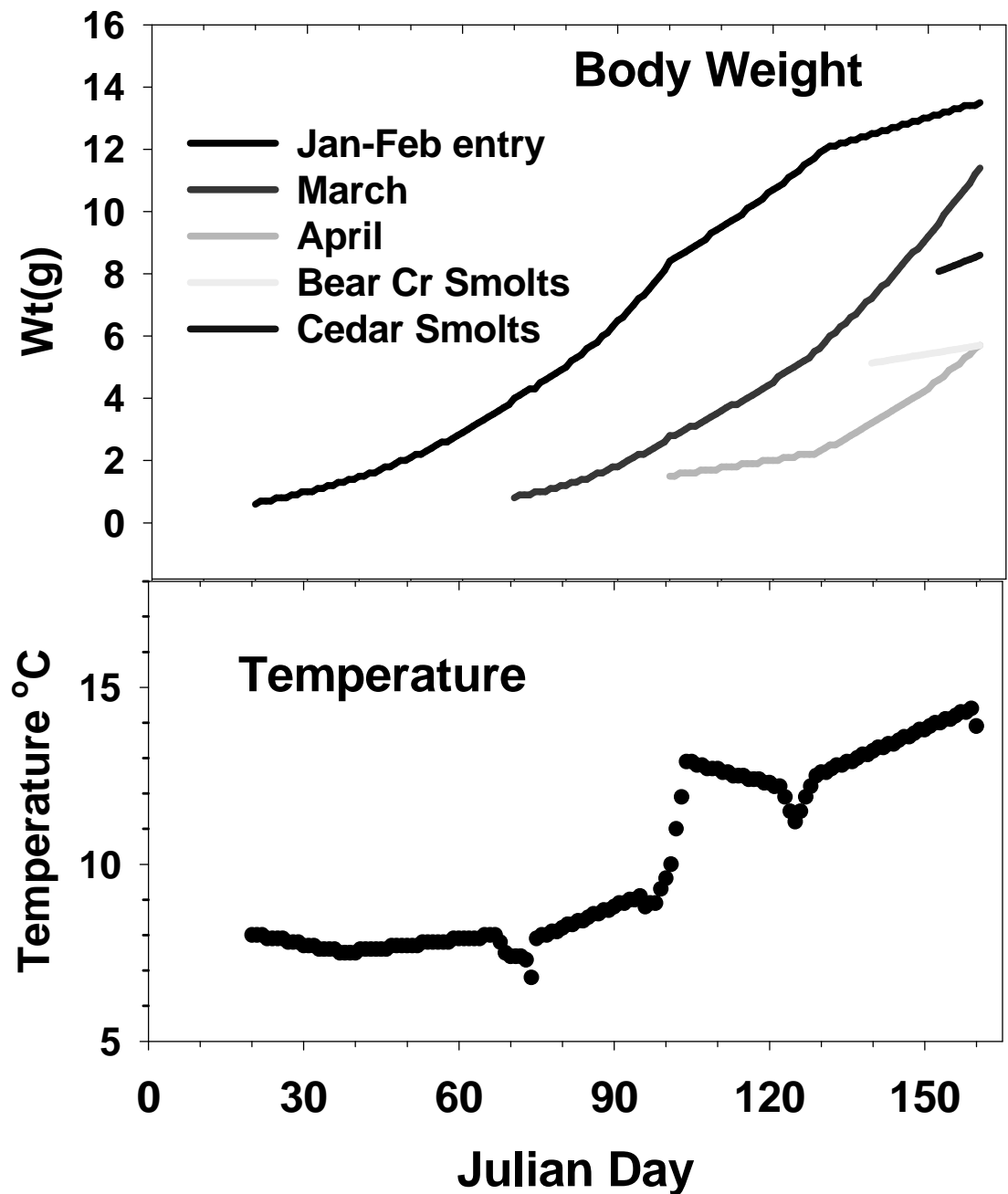
# Diet of hatchery and wild fish

- Wild and hatchery chinook consume similar types of prey in different proportions.

		<u>Percent of Total Biomass</u>	
		Hatchery Chinook June only	Wild Chinook Feb-June
•ZOOPLANKTON		82%	19%
•AQUATIC INSECTS		7%	68%
•TERRESTRIAL INSECTS		1%	3%
•OTHER		10%	10%
•MEAN FORK LENGTH (mm)		115	98

# Growth Performance

- All Migrant Cohorts exhibit Positive Growth
- Early Lake-Entry results in Larger body size in June than Smolts from Bear Cr or Cedar R



- Temperature increased Monthly

- Max. Temp. modified by fish moving into thermocline

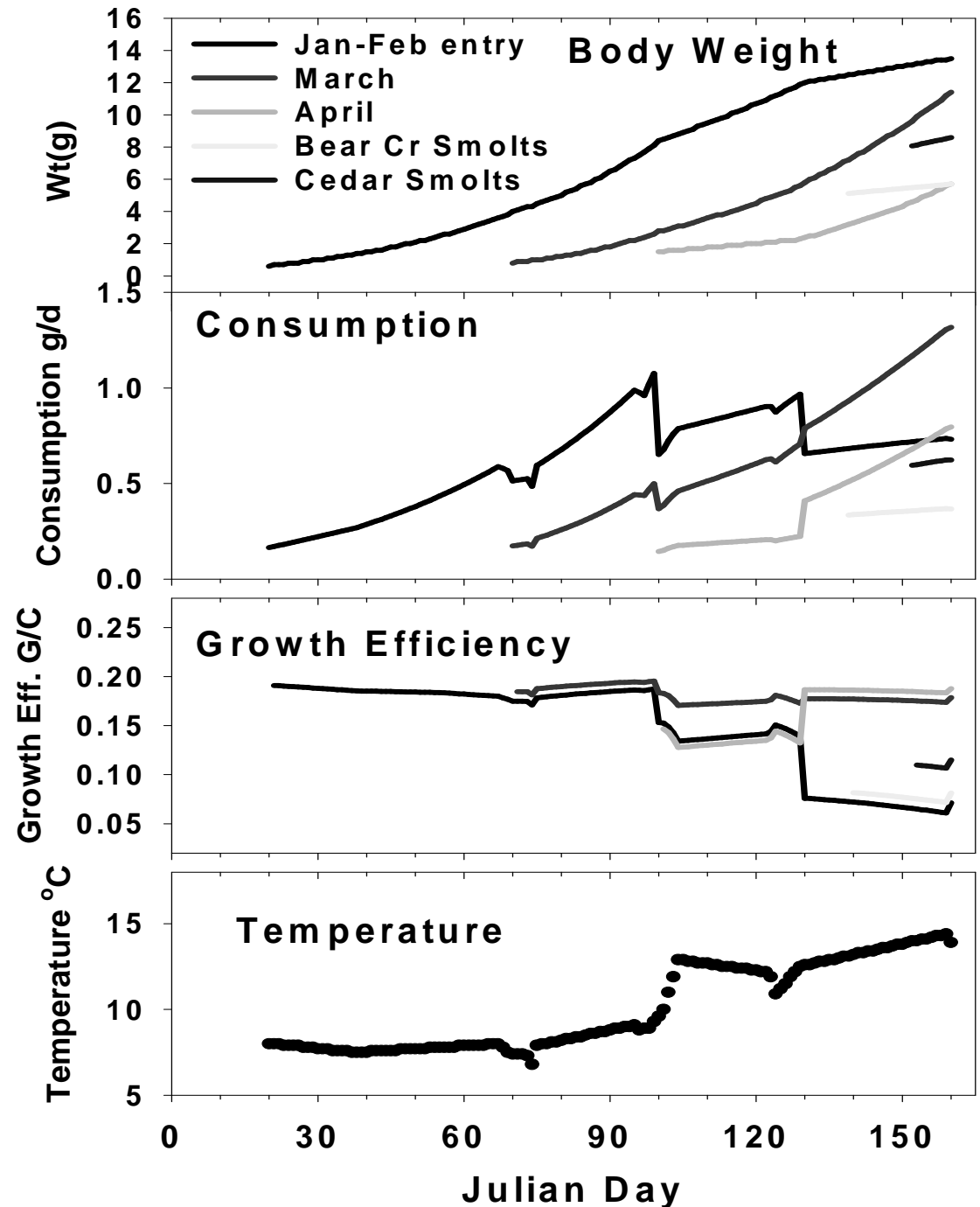
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- Consumption rates vary among Groups and Months
- Consumption responds to changes in Temperature & Diet

- Growth Efficiency generally declined for most cohorts during mid-April through June
- GE responds to changes in Temperature & Food Quality

- Temperature increased Monthly

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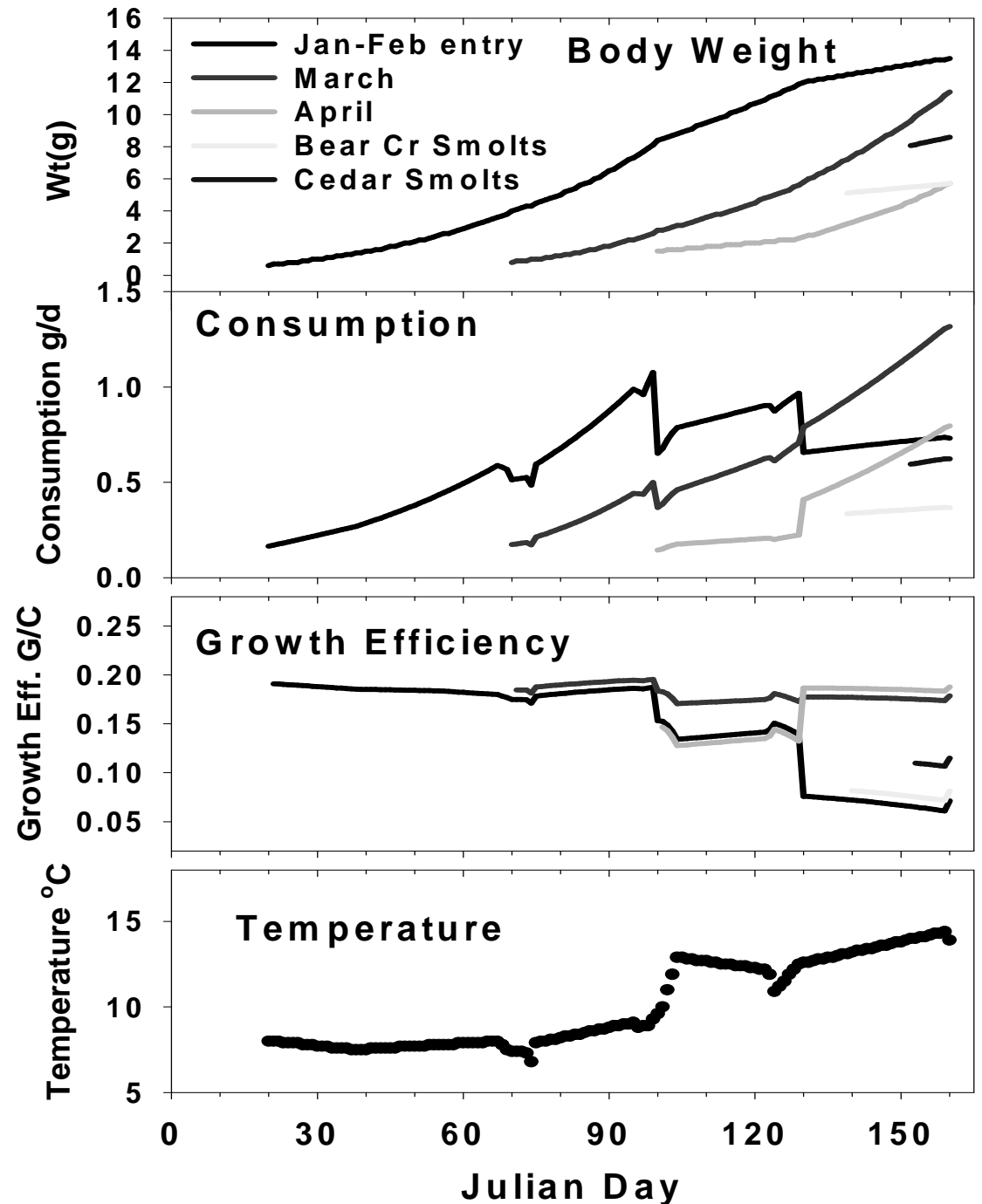
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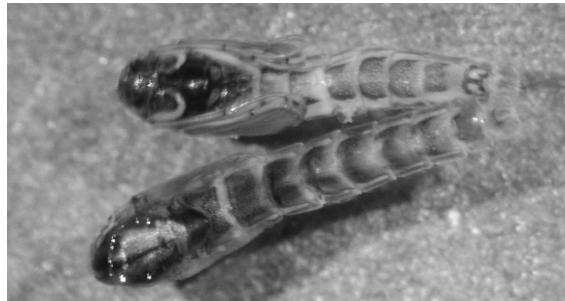
# *Growth and Feeding Performance in Lake Washington*

## Bioenergetics Approach:

Consumption = Metabolism + Waste + Growth

*Size • Temperature • Food Availability*

In Lake Washington...



3400 – 4500 J/g



4000 J/g

High growth rates!

# *How does growth in Lake Washington compare to growth in estuaries?*

## Bioenergetics Approach:

$$\text{Consumption} = \text{Metabolism} + \text{Waste} + \text{Growth}$$

*Size • Temperature • Food Availability*

In estuaries...



2400 - 2500 J/g



3400 – 4500 J/g



4000 J/g



4200 - 7600 J/g

Rapid, but variable growth

# REARING



Lake Washington



Estuary

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Behavior: Small chinook use nearshore habitats, larger fish move to offshore habitats

✓

✓

---

Prey: emergent and terrestrial insects and epibenthic organisms in the nearshore, zooplankton in offshore habitats

✓

✓

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Opportunity for growth before ocean

✓

✓

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Refugia from predators

?

✓

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Physiological adaptation to saltwater

NO!

✓

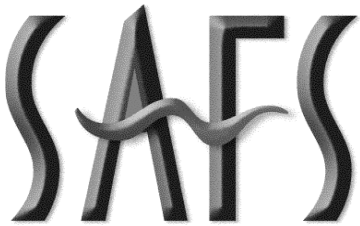
# Conclusions

- Lake-rearing Chinook exhibited high consumption and growth
- Stream-type smolts are smaller than lake-rearing juveniles
- Littoral distribution and forage base (chironomids) important through May
- Shift to pelagic forage base (*Daphnia*) in June-joined by Hatchery Chinook & Coho
- Food supply not currently a limiting factor!
- Predation probably the greatest limitation

# Acknowledgements

*Funded by METRO King County and WDFW*

*Additional support from Cities of Seattle (SPU) & Bellevue*



SCHOOL OF  
AQUATIC  
and  
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